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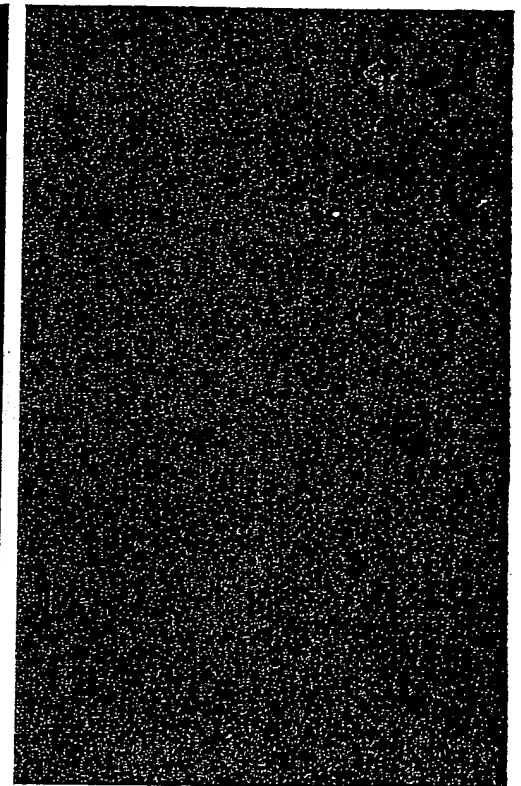
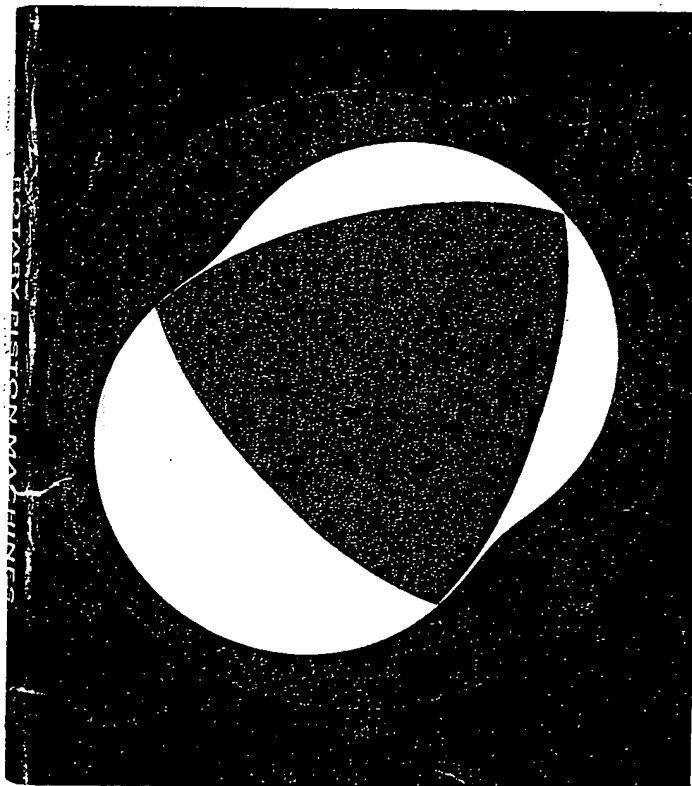
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*Classification of design  
principles for engines,  
pumps and compressors*

# ROTARY PISTON MACHINES



Felix Wankel

gement (A), cam-engagement (Co) and external-axis

gaging components.

parallel circular arcs. The equal r.p.m.<sup>1</sup> and equal

of engaging gears.

r.p.m.<sup>1</sup> has fewer teeth<sup>2</sup>.  
greater number of teeth<sup>2</sup>.  
p.m. have equal numbers

or r.p.m.<sup>1</sup> has few<sup>2</sup> teeth.  
lower r.p.m.<sup>1</sup> possesses a

ual r.p.m.<sup>1</sup> possess equal







ct point in same direction

possesses fewer<sup>2</sup> teeth.  
possesses more<sup>2</sup> teeth.

engaging point in opposite

in.  
of components performing an













## Significance of the colour code

-  Piston-runner or rotor (output component)
-  Sealing-rotor (sealing component)
-  Alternating or simultaneous piston or rotor and sealing component
-  Stationary chamber wall
-  Crank
-  Sealing element

## Illustrations of engagement methods

### Internal-axis SIM

Similar arrangement to the axes of an external-tooth gear meshing with internal tooth ring gear

Principle of Engagement	I. Reciprocating engagement (R)	II. Arctuate engagement (A)	III. Cam engagement (Ca) or (Ci)	IV. Slip engagement (S)	V. Counter engagement (Co) or (Coe)
Example of models	Impossible as SIM machines				
Diagrammatic sketch, arrows indicate direction of rotation					
Distinguishing mark		At point of contact the rotating parts move in same direction. Engaging parts pursue parallel circular paths. They revolve at equal r.p.m.	At point of contact motion is in same direction. Engaging component with smaller diameter and higher speed has fewer teeth. Larger diameter part running at lower speed has more teeth.	At contact point rotation in same direction. Larger diameter part with higher speed has fewer teeth. Smaller diameter part with lower speed has more teeth.	Direction of rotation at contact point in opposite direction. Speed ratio may be anything provided it is a whole number.
Gear connections between axes					

### 3

#### External-axis SIM

Similar to the axes of a pair of meshing spur gears

Principle of Engagement	I. Reciprocating engagement (R)	II. Arcuate engagement (A)	III. Cam engagement (Ci) or (Ca)	IV. Slip engagement (S)	V. Counter engagement (Co) or (Coe)
Example of models	Impossible as SIM machines	Impossible with external-axis SIM machines		Cam engagement cannot form chambers on external-axis machines.	
Diagrammatic sketch, arrows indicate direction of rotation					
Distinguishing mark			At contact point rotation in same direction. Component with equal or unequal diameter and higher speed has fewer teeth. Component with equal or unequal diameter and lower speed has more teeth. Component with equal or unequal diameter and equal speed has equal number of teeth.		Direction of rotation at contact point in opposite direction. Speed ratio may be anything provided it is a whole number.
Gear connections between axes					

#### Internal-axis PLM with outer piston-rotor rotating about its own

Principle of Engagement	I. Reciprocating engagement (R)
Example of models	
Diagrammatic sketch, arrows indicate direction of rotation	
Distinguishing mark	Linear motion between the engaging component. Piston-rotor rotates in opposite direction to crank at half crank speed relative to housing. Sealing component also rotates in same direction at half crank speed relative to casing.
Gear connections between axes	

### 4

Internal-axis PLM with inner piston-rotor similar to the arrangement of axes of pinion and internal-tooth ring gear, the piston-rotor revolving about its own centre of gravity

Principle of Engagement	I. Reciprocating engagement (R)	II. Arcuate engagement (A)	III. Cam engagement (Ci) or (Ca)	IV. Slip engagement (S)	V. Counter engagement (Co) or (Coe)
Example of models					
Diagrammatic sketch, arrows indicate direction of rotation					
Distinguishing mark	Linear motion between the engaging components. Piston-rotor rotates in opposite direction to crank at half crank speed relative to housing. Sealing component also rotates in same direction at half crank speed relative to casing.	Circular parallel motion of the engaging components. Piston-rotor revolves in opposite direction to crank but at the same speed as the crank relative to the casing.	Rolling motion at engagement point. Piston-rotor revolves in opposite direction to crank but at higher speed than the crank relative to casing. Engaging component with smaller diameter and higher speed has smaller number of teeth. Engaging component with larger diameter has more teeth.	Rolling motion at engaging point. Piston-rotor revolves in opposite direction to crank but at lower speed relative to casing. Engaging component with larger diameter has fewer teeth. Engaging component with smaller diameter and lower speed has more teeth.	Counter movement at point of contact. Piston-rotor revolves at equal speed round crank pin at any speed ratio to crank relative to casing provided it is a whole number.
Gear connections between axes					

#### External-axis PLM have axes which itself follows a circular path

Principle of Engagement	I. Reciprocating engagement (R)
Example of models	
Diagrammatic sketch, arrows indicate direction of rotation	
Distinguishing mark	Linear motion of engaging components. Piston-rotor revolves in opposite direction to crank and at the same speed relative to the casing. Crankshafts rotate in opposite directions.
Gear connections between axes	

**Internal-axis PLM** with outer piston-rotor similar to the arrangement of axes of pinion and internal tooth ring gear, piston-rotor rotating about its own centre of gravity

Engagement (S)	V. Counter engagement (Coi) or (Coe)
Engagement cannot be used on these machines.	
	Direction of rotation at contact point in opposite direction. Speed ratio may be anything provided it is a whole number.

Principle of Engagement	I. Reciprocating engagement (R)	II. Arctuate engagement (A)	III. Cam engagement (Ci) or (Ce)	IV. Slip engagement (S)	V. Counter engagement (Coi) or (Coe)
Example of models					
Diagrammatic sketch, arrows indicate direction of rotation					
Distinguishing mark	Linear motion between the engaging components. Piston-rotor rotates in opposite direction to crank at half crank speed relative to housing. Sealing component also rotates in same direction at half crank speed relative to casing.	Circular parallel motion of the engaging components. Piston-rotor revolves in opposite direction to crank but at the same speed as the crank relative to the casing.	Rolling motion at engagement point. Piston-rotor revolves in opposite direction to crank at lower speed than the crank relative to casing. Engaging component with smaller diameter has fewer teeth. Larger diameter part with lower speed has more teeth.	Rolling motion at engagement point. Piston-rotor revolves in opposite direction to crank at higher speed relative to casing. Engaging component with larger diameter and higher speed has fewer teeth. Larger diameter part has more teeth.	Counter movement at point of contact. Piston-rotor revolves at equal speed round crank pin at any speed ratio to crank relative to casing provided it is a whole number.
Gear connections between axes					

**External-axis PLM** have axes similarly arranged to meshing spur gears and the rotating piston-rotor revolves round its c.g. which itself follows a circular path

Engagement (S)	V. Counter engagement (Coi) or (Coe)
	Sealing component if present = crank
at l. volves in tion to wer speed ing. onent with r has	Counter movement at point of contact. Piston-rotor revolves at equal speed round crank pin at any speed ratio to crank relative to casing provided it is a whole number.

Principle of Engagement	I. Reciprocating engagement (R)	II. Arctuate engagement (A)	III. Cam engagement (Ci) or (Ce)	IV. Slip engagement (S)	V. Counter engagement (Coi) or (Coe)
Example of models				Cam engagement cannot form chambers on external-axis machines.	
Diagrammatic sketch, arrows indicate direction of rotation					
Distinguishing mark	Linear motion of engaging components. Piston-rotor revolves in opposite direction to crank and at the same speed relative to the casing. Crankshafts rotate in opposite directions.	Circular parallel motion of the engaging components. Piston-rotor revolves in opposite direction to crank and at the same speed relative to casing. Crankshafts rotate in the same direction.	Rolling motion at engaging point. Piston-rotor revolves in the same direction relative to housing. Engaging component with equal or unequal diameters and higher speeds have fewer teeth. Engaging component with equal or unequal diameters and lower speeds have more teeth. Engaging component with equal or unequal diameters have equal number of teeth.		Counter rolling movement at contact point. Piston-rotor revolves in opposite direction to crank pin at any speed ratio relative to crank, provided it is a whole number.
Gear connections between axes					

**7**

		INTERNAL-AXIS									
		no stationary chamber walls		outer or inner stationary chamber walls				stationary outer & inner chamber walls		no stationary chamber walls	
				outer	inner	outer	inner				outer
I.	Reciprocating engagement										
II.	Arctuate engagement										
III.	Cam engagement										
IV.	Slip engagement										
V.	Counter engagement										
VI.	Reciprocating & slip engagement Similar to slip engagement										
VII.	Arctuate and reciprocating engagement										
VIII.	Engagement similar to arctuate and reciprocating engagement										
IX.	Engagement similar to arctuate engagement										
X.	Arctuate engagement with pendulum RP or SC										
XI.	Engagement similar to cam engagement with pendulum RP or SC										
XII.	Slip- and counter engagement										











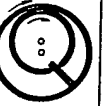





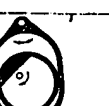
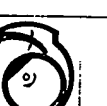
stationary outer & inner chamber walls			EXTERNAL-AXIS						stationary outer & inner chamber walls	
inner			no stationary chamber walls	outer	inner	outer	inner			

# 8 Classification of planetary-rotation machines (PLM)

	INTERNAL-AXIS								stationary outer and inner chamber walls	no chamber walls	
	no stationary chamber walls				outer or inner stationary chamber walls						
					outer	inner	outer	inner			
I. Reciprocating engagement											
II. Arcuate engagement											
III. Cam engagement											
IV. Slip engagement											
V. Counter engagement											
VI. Reciprocating & slip engagement. Similar to slip engagement											
VII. Arcuate and reciprocating engagement											
VIII. Engagement similar to arcuate and reciprocating engagement											
IX. Engagement similar to arcuate engagement											
X. Arcuate engagement with pendulum RP or SC											
XI. Engagement similar to cam engagement with pendulum RP or SC											
XII. Slip- and counter engagement											
	1	2	3	4	5	6	7	8	9	10	11



















# 9 Classification of single-rotation rotating-piston machines (SRPM)

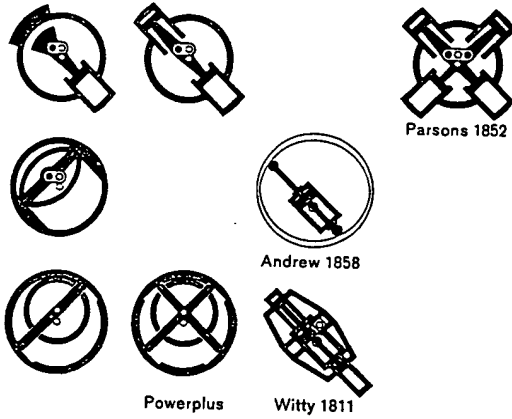
	INTERNAL-AXIS						EXTERNAL-AXIS				
	no stationary chamber walls	outer or inner stationary chamber walls				stationary outer and inner chamber walls	no stationary chamber walls	outer			
		outer	inner	outer	inner						
I. Reciprocating engagement											
II. Arctuate engagement											
III. Cam engagement											
IV. Slip engagement											
V. Counter engagement											
VI. Reciprocating & slip engagement. Similar to slip engagement											
VII. Arctuate and reciprocating engagement											
VIII. Engagement similar to arctuate and reciprocating engagement											
IX. Engagement similar to arctuate engagement											
X. Arctuate engagement with pendulum RP or SC											
XI. Engagement simil. to cam engagement with pendul. RP or SC											
XII. Slip- and counter engagement											
	1	2	3	4	5	6	7	8	9	10	11

# 10 Classification of rotating-piston machines with engagement similar to arctuate engagement (PROM)

		INTERNAL-AXIS										
		no stationary chamber walls				outer or inner stationary chamber walls				stationary outer and inner chamber walls		
						outer	inner	outer	inner			
I.	Reciprocating engagement											
II.	Arctuate engagement											
III.	Cam engagement											
IV.	Slip engagement											
V.	Counter engagement											
VI.	Reciprocating & slip engagement. Similar to slip engagement											
VII.	Arctuate and reciprocating engagement											
VIII.	Engagement similar to arctuate and reciprocating engagement											
IX.	Engagement similar to arctuate engagement											
X.	Arctuate engagement with pendulum RP or SC											
XI.	Engagement siml. to cam engagement with pendul. RP or SC											
XII.	Slip- and counter engagement											
		1	2	3	4	5	6	7	8	9	10	11

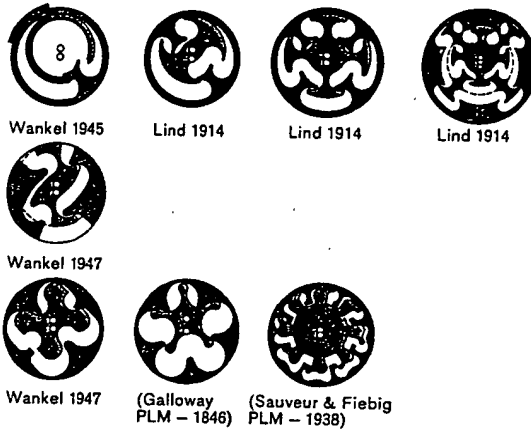
EXTERNAL-AXIS										CENTRAL-AXIS					
inner	stationary outer and inner chamber walls		no stationary chamber walls	outer or inner stationary chamber walls				stationary chamber walls	No stationary chamber walls	outer or inner stationary chamber walls		Stationary outer or inner chamber walls			
				outer	inner	outer	inner								
															
															
															
															
6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	

# 11 Model Sheet



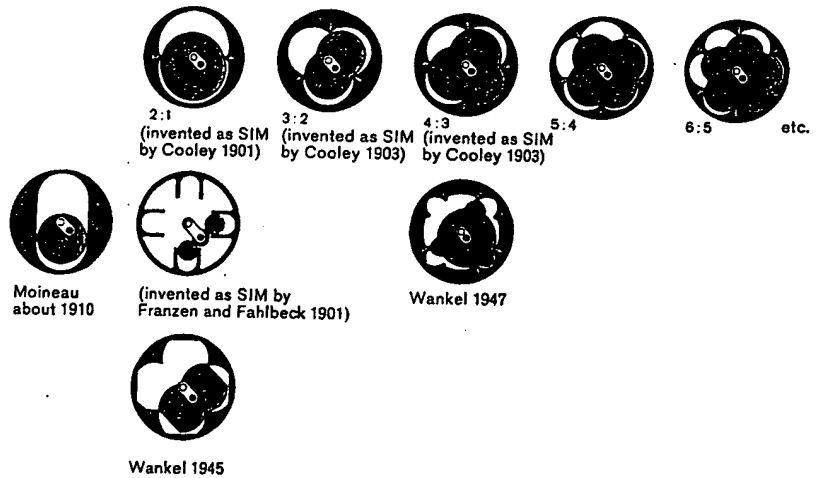
Types of internal-axis machines PLM (R) Chart 8 I/1

# 12 Model Sheet



Types of internal-axis machines SIM (A) Chart 7 II/2

# 13 Model Sheet



Types of internal-axis PLM (Ce) Chart 8 (PLM) III/7



2:1  
Wankel 1954



Wankel 1944



Wankel 1962

Types of intern.



2:1

Types of intern



1:2

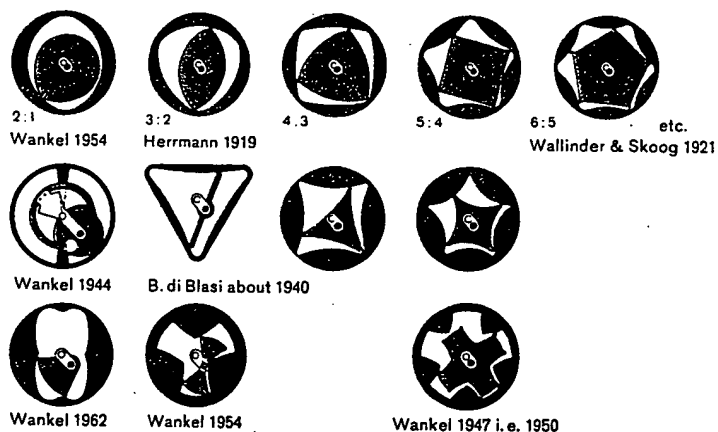
Types of intern



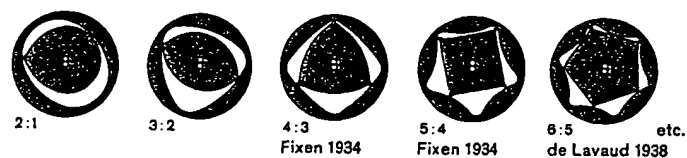
1:2



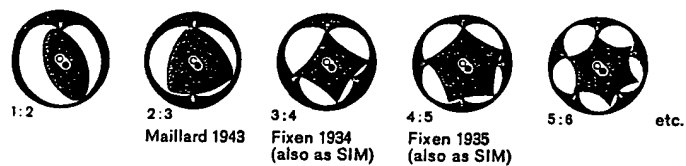
Types of intern.



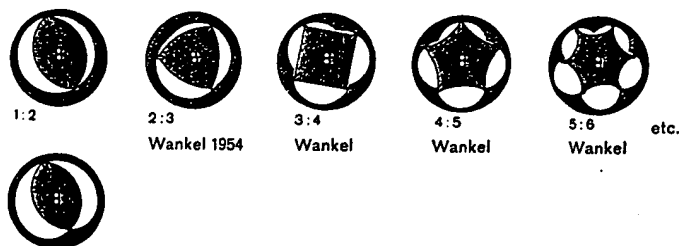
Types of internal-axis PLM ( $\overline{C_1}$ ) Group PLM III/5



Types of internal-axis SIM ( $\overline{C_1}$ ) Group SIM III/2

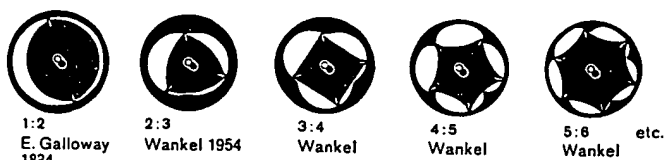


Types of internal-axis PLM ( $\overline{S_1}$ ) Group PLM IV/7



Types of internal-axis SIM ( $\overline{S_1}$ ) Group SIM IV/2

# 18 Model Sheet

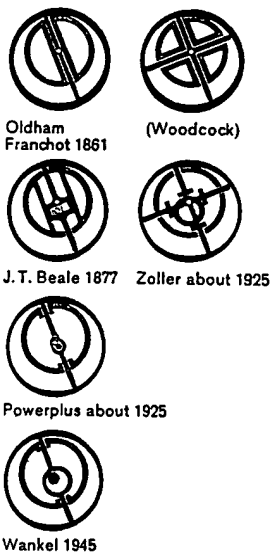


Types of internal-axis PLM (Sli) Group PLM IV/5



Internal-axis PLM IV Slip-engagement

# 19 Model Sheet



Types of internal-axis PLM (S+R) Group PLM VI/5



Internal-axis PLM III Cam-engagement ROPIMA machine



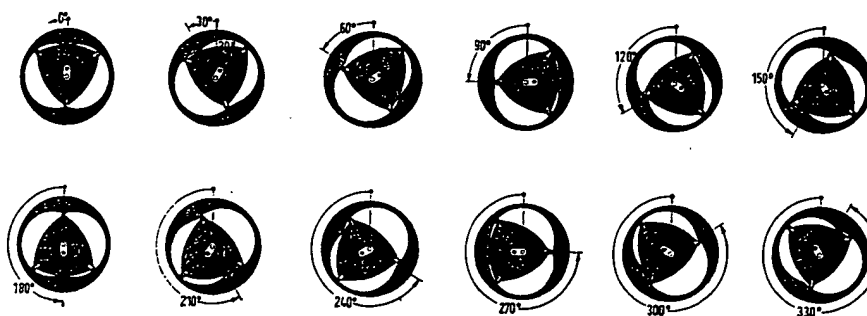
Ramelli 1588



Emery 1869

Types of internal-

# 20 Phasing Diagram



Diagrammatic arrangement of relative rotor positions of 2:3 machine, outer rotor has additional PLM rotation



Trotter 1805  
Types of internal-



Types of external-



etc.



Internal-axis PLM (Sli)  
IV Slip-engagement 2:3



Internal-axis PLM (Sle)  
III Cam-engagement 3:2



Dillenberg 1961  
Internal-axis PROM  
IX Arctuate-engagement



Internal-axis PLM (Sle)  
III Cam-engagement 2:1



Internal-axis PLM (Sle)  
III Cam-engagement 2:1

ROPIMA machines with additional motion which is not required

Special Sheet **21**



Ramelli 1588



Wittig about 1900



Emery 1869



Davies 1867



Jones & Shirreff 1856

Types of internal-axis PROM machines Group PROM VI/5

Model Sheet **22**



Trotter 1805



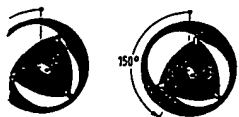
Cochrane 1830



Fletcher 1843

Types of internal-axis SROM machines Group SROM IX/3

Model Sheet **23**



or has additional PLM rotation



Tänzler 1937



Tänzler 1937



Tänzler

Types of external-axis PROM machines Group PROM X/11

Model Sheet **24**

## 25 Model Sheet



Types of internal-axis PROM machines Group PROM X/5

## 26 Model Sheet



Ramelli 1588

Cochrane

Turboflex

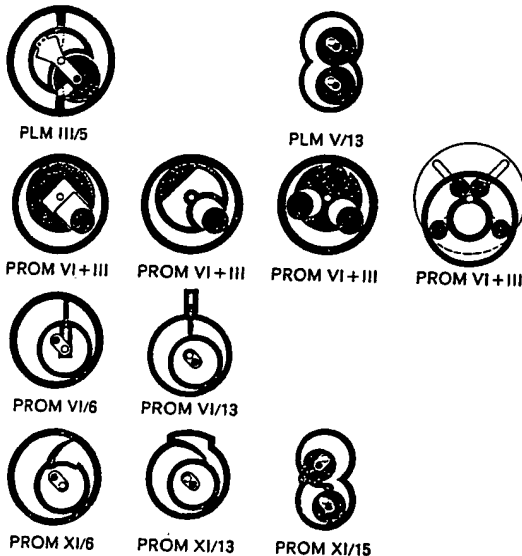


Geiger 1960

Sugopump

Types of internal-axis PROM machines Group PROM XI/5

## 27 Sheet of Comparisons



PLM and PROM machines with rolling-piston rotor

## Special Ter Rotary Pist

HKM = Hubkolb  
RKM = Rotation  
DKM = D = Dre  
KKM = K = Kre  
UKM = Umlaufk  
DU = Drehkolb  
Umlaufk  
KU = Kreiskoll  
Umlaufk

(K) = Kammein  
(S) = Schlupfei  
(KR) = Kreiseing  
(G) = Gegeneir  
(H) = Hubeingr

\* Parallelachsige  
\* Parallel-außena  
\* Parallel-innenac  
\* Mittelachsige M  
\* Winkelachsige I  
\* Winkel-außenac  
\* Winkel-innenac  
\* Geschränktachs  
\* Geschränkt-auß  
\* Geschränkt-inne

Bauarten  
Bauformen  
Schwerpunktverh.  
Kolbenlaufer KL  
Schwingbaum  
Wagnerscher Han

Abspernteil = AL

Einteilungs- oder  
Umlaufkolben-Ste  
Kurvenerzeugung  
Verzahnungskörp  
Paarkolben  
Paarflügelkolben  
Paarschieber  
Eingriffskörper  
Arenakurven  
Schädlicher Raum  
Kardankreisgetrie  
Kardankreisgetrie  
Querzylindrisch  
Ovalzahnäder



## Special Terms and Expressions Used in Conjunction with Rotary Piston Machines

HKM = Hubkolbenmaschine	REM = reciprocating-piston machine
RKM = Rotationskolbenmaschine	ROPIMA = Rotary piston machine
DKM = D = Drehkolbenmaschine	SIM = Single rotation machine
KKM = K = Kreiskolbenmaschine	PLM = planetary-rotation machine
UKM = Umlaufkolbenmaschine	ROM = Rotating-piston machine
DU = Drehkolbenartige Umlaufkolben-Maschine	SROM = Rotating-piston machine similar to single- rotation machine
KU = Kreiskolbenartige Umlaufkolben-Maschine	PROM = Rotating-piston machine similar to plane- tary-rotation machine
(K) = Kammeingriff	(C) = Cam engagement (or meshing)
(S) = Schlupfeingriff	(Sl) = slip engagement (or meshing)
(KR) = Kreiseingriff	(A) = arcuate engagement (in circular arc)
(G) = Gegeneingriff	(Co) = counter engagement
(H) = Hubeingriff	(R) = reciprocating engagement
* Parallelachsige RKM	ROPIMA machines with parallel axes
* Parallel-außenachsige RKM	ROPIMA machines with external axes
* Parallel-innenachsige RKM	ROPIMA machines with internal axes
* Mittelachsige Maschinen	Central axis machines
* Winkelachsige Maschinen	Machines with axes inclined towards each other
* Winkel-außenachsige Maschinen	Machines with external axes inclined
* Winkel-innenachsige Maschinen	Machines with internal axes inclined
* Geschränktachsige RKM	ROPIMA intersecting or crossed axis machine
* Geschränkt-außenachsige RKM	ROPIMA intersecting external axis machine
* Geschränkt-innenachsige RKM	ROPIMA intersecting internal axis machine
Bauarten	types
Bauformen	models, versions
Schwerpunktverhalten	behaviour of the centre of gravity
Kolbenlaufer KL	RP = runner, rotor, rotating piston
Schwingbaum	rocking beam or swinging beam
Wagnerscher Hammer	electric bell actuating device said to have been invented by: John Maraud (E) J. P. Wagner (G) Neff (F) Page (USA)
Abspernteil = AL	SC = Sealing or containing components, not seal- ing element
Einteilungs- oder Systemblatt	classification chart
Umlaufkolben-Sternflugmotor	radial aircraft engine, Gnome le Rhône
Kurvenerzeugungspunkte	curve generating points
Verzahnungskörper	(tooth) generating part or body
Paarkolben	double, double acting or pair of pistons
Paarflügelkolben	single vane right through rotor
Paarschieber	sliding vane valve
Eingriffskörper	catch, pawl, engaging or meshing
Arenakurven	oval track shaped like circus arena
Schädlicher Raum	Volume contained at TDC
Kardankreisgesetz	Principle of HYPOCYCLOID ( $R = 2r$ )
Kardankreisgetriebe	Epicyclic or planetary gearbox
Querzylindrisch	Cylinder transverse or parallel to axis of rotation
Ovalzahnräder	Oval gears (used in counting machines)